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THE USE OF CLOUDSAT AND CALIPSO FOR THE VALIDATION OF OPERATIONAL CLOUD PRODUCTS

With the launch of the CALIPSO and CloudSat missions into the EOS A-train, NASA has provided an unprecedented opportunity for validation of cloud products generated from the current suite of passive satellite radiometers (imagers and sounders). Both of these missions provide information on the vertical profile of cloud properties that has never been available in the quantity and with the spatial coverage provided by these sensors.

This report summarizes current NOAA efforts to use this new data source to validate operational cloud products. One additional goal of this work is to use CALIPSO and CloudSat to generate error-bars on the 30 years time series of cloud products provided by ISCCP, PATMOS-x and other satellite cloud climatologies.

THE USE OF CLOUDSAT AND CALIPSO TO VALIDATE OPERATIONAL CLOUD PRODUCTS

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1. INTRODUCTION

With the launch of the CALIPSO and CloudSat missions into the EOS A-train, NASA has provided an unprecedented opportunity for validation of cloud products generated from the current suite of passive satellite radiometers (imagers and sounders). Both of these missions provide information on the vertical profile of cloud properties that has never been available in the quantity and with the spatial coverage provided by these sensors.

This report summarizes are current efforts at using this new data source to validate operational cloud products. One additional goal of this work is to use CALIPSO and CloudSat to generate error-bars on the 30 years time series of cloud products provided by ISCCP, PATMOS-x and other satellite cloud climatologies. Fortunately, CALIPSO and CLOUDSAT are available at time when the AVHRR, a source of imager data for the past 30 years, and MODIS, an advanced imager, are available.

CALIPSO and CloudSat provide vertical profiles of cloud ice and water distributions along a nadir strip within the MODIS/AQUA swath.

2. MAIN TEXT

CALIPO and CloudSat were launched on April 28, 2006 into a 13:30 sun synchronous orbit in formation with the EOS/AQUA platform. Therefore, these sensors provide a continuous stream of co-located observations with the EOS/AQUA sensors (i.e. AIRS, MODIS, and AMSR-e). In addition, orbital intersections between the A-train and other platforms such as POES, GOES and MSG have been computed and allow for validation of cloud products from operational platforms. Onboard each of these satellites are instruments that provide information on the vertical profile of clouds that has never been available from space before. On CALIPSO, the Clouds-Aerosol Lidar with Orthogonal Polarization (CALIOP) provides information with a spatial resolution of roughly 330 m and vertical resolution of roughly 50 m. On CloudSat, the 94 GHz cloud profiling radar (CPR), provides data with a vertical resolution of 500m and a spatial resolution of roughly 2000m

Our main effort to date has been in the development of methods that exploit the new information provided by CALIPSO and CLOUDSAT (referred to as CC hereafter). Our efforts have been focused using CC along with MSG/SEVIRI data to develop and validate algorithmic approaches for GOES-R Advanced Baseline Imager (ABI) and to validate the Clouds from AVHRR Extended (CLAVR-x) algorithms run operationally by NOAA. The following sections go into more detail on these efforts.

Validation of Cloud Height Approaches for GOES-R

The SEVIRI on MSG provides the best spatial, spectral and temporal match of any current instrument to the GOES-R ABI. Cloud height is a critical product because it is not only a fundamental climate parameter but it is relied upon by other algorithms (such as wind and cloud microphysical retrievals and convection initiation studies). We have developed techniques to allow CC observations to be used throughout the algorithm validation and development process.

Traditionally, cloud heights are validated by directly comparing the cloud top height measured by the lidar to the cloud top height retrieved by the passive sensor. In compiling the final validation statistics, some filtering of the data is usually performed. For instance, multi-layered cloud scenes are usually excluded from the analysis. While this method of validation gives some insight into systematic biases, it does not help to physically explain why the biases exist. Nor does it give specific insight into the validity of each aspect of the algorithm methodology. Every operational cloud height algorithm, whether it be the 11-μm/13.3-μm ratio technique, IR-window look-up, CO_2 slicing, or otherwise is governed by certain underlying assumptions. These assumptions are often manifested in cloud opacity (e.g. the IR-window look-up method) or the spectral variation of cloud emissivity (e.g. the CO_2 ratio technique). It is important to note that the spectral variation of cloud emissivity is directly related to the cloud microphysics (size, phase, and habit). The validation should be performed as a function of cloud emissivity, cloud microphysics, and cloud layers. Also, cirrus clouds are observed to overlap lower cloud layers at least 40% of the time (Heidinger and Pavolonis, 2005). Cloud height performance needs to be characterized under such conditions, since they are so common. Validation analysis should lead to improvements in algorithm performance under difficult conditions such as multilayered cloud scenes. Thus, these types of scenes should not be ignored. CC provides, for the first time, the observations needed to properly diagnose algorithm performance. Figure 1 illustrates the information provided by CALIPSO. The top panel shows a 2 dimensional backscattering profile at 532 nm which is the fundamental measurement by CALIPSO. In the bottom panel, the magenta regions correspond to the cloud layers provided in the standard CALIPSO output.

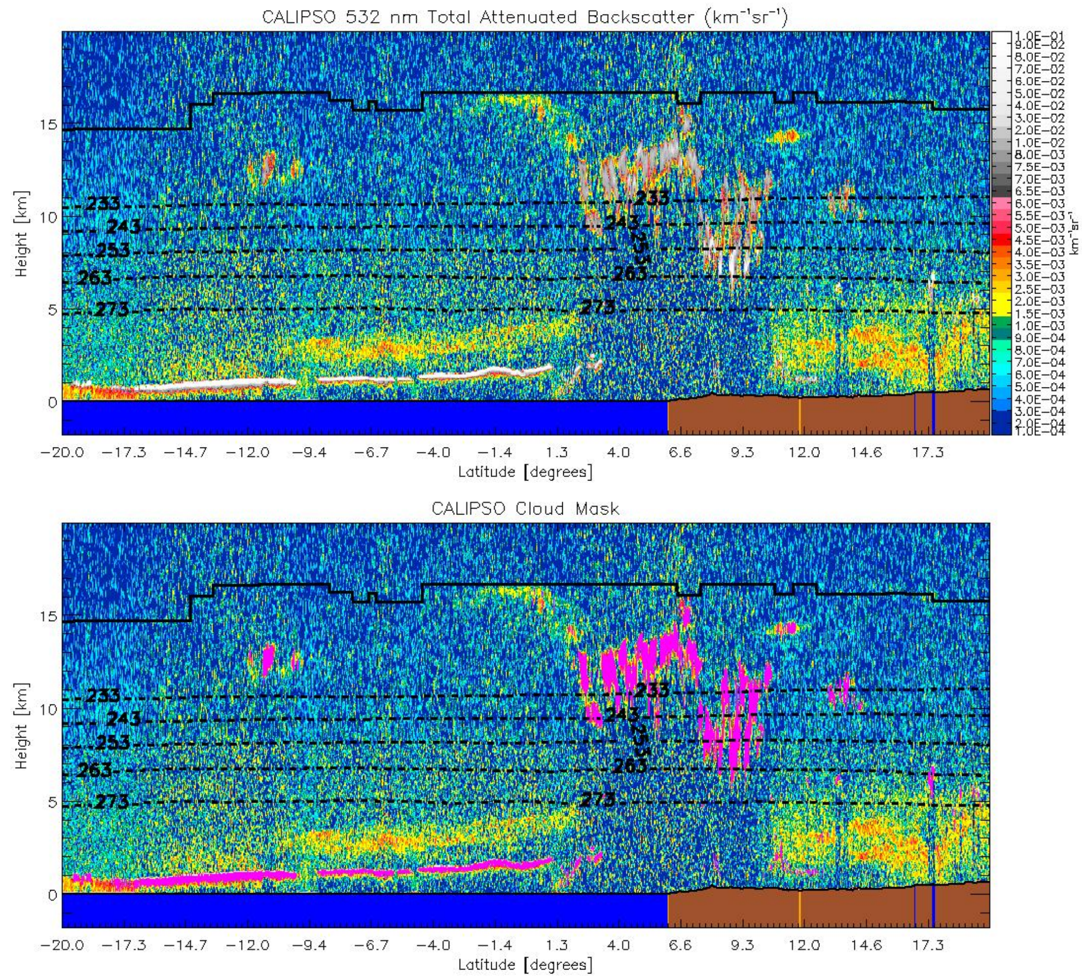

Figure 1. Illustration of the CALIPSO data used in this study. Top image shows a 2d backscatter profile. Bottom image shows the detected cloud layers overlaid onto the backscatter image. Cloud layers are colored magenta.

CloudSat also provides similar information to that shown above. While CloudSat can not detect thin cirrus, it can detect opaque cloud. Therefore CALIPSO and CloudSat need to be combined to provide a fuller representation of the cloud vertical distribution. The public release of combined CloudSat and CALIPSO products will happen soon.

Validation of Cloud Products from the AVHRR

Compared to advanced imagers such as MODIS, the AVHRR provides data a greatly reduced spectral resolution. With the launch of METOP, AVHRR data is now available globally and operationally with a resolution of 1 km. Therefore the AVHRR remains a vital component of the global cloud observing system. In addition, the AVHRR has provided consistent observations over past 25 years and is therefore a critical component of the satellite climate observing system.

Figure 2 illustrates the progress we have made in using CALIPSO data to validate operational AVHRR products from NOAA. Figure 2 shows the variation in the differences in cloud top pressure as a function of the derived CALIPSO cloud emissivity. The results indicate that for values of cloud emissivity less than 0.4, AVHRR estimates of cloud top pressure exhibit errors exceeding 40 hPa. While this performance degradation is expected, CALIPSO data provides the quantitative verification of AVHRR algorithm's behaviour.

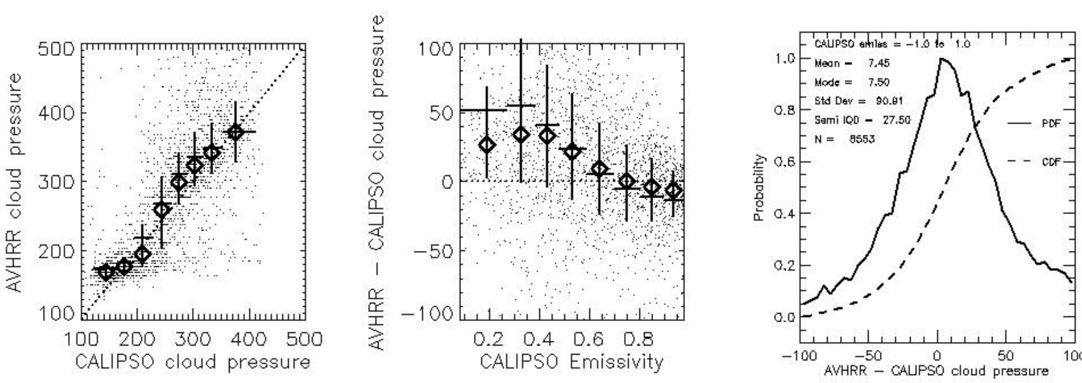

Figure 2. Example comparisons from co-located NOAA-18/AVHRR CLAVR-x cloud top pressures and those from CALIPSO for August 2006. Diamonds represent the mode of the results within each bin. Distribution shown on the right is for all points.

3. CONCLUSIONS AND FUTURE WORK

The CloudSat and CALIPSO (CC) data are providing new opportunities for validation of operational sensors. Our work with CC for cloud product validation has just begun. We envision working on the following over the next year.

- Continued refinement of validation approaches for GOES-R ABI algorithms applied to SEVIRI data.

- Using CC data to develop confidence levels on the AVHRR Pathfinder Atmosphere Extended (PATMOS-x) cloud climatology

- Extending validation to cloud phase and cloud ice/liquid water paths as these products become available from CC.

- Using the microphysical information from CC to further stratify algorithm performance.

References

Heidinger, Andrew K. and Pavolonis, Michael J.. **Global daytime distribution of overlapping cirrus cloud from NOAA's Advanced Very High Resolution Radiometer**. Journal of Climate, Volume 18, Issue 22, 2005, pp.4772-4784